A MID–LATE HOLOCENE VEGETATION RECORD FROM AN INTERDUNAL SWAMP, MORNINGTON PENINSULA, VICTORIA

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Palynological analysis of swamp sediments from an interdunal swale provides a vegetation and environmental history from *c.* 4500 years BP to present. Although essentially the same vegetation communities of the site and surrounding area are recorded through the period, their distributions have changed due to regional climatic variation and human influence, particularly the impact of European land settlement. Changes in aquatic plant assemblages are related to localised fluctuations in the hydrological regime. *Melaleuca* and Cyperaceae have persisted as dominant taxa, with the hydrophyte *Villarsia* increasing in importance with a change from ephemeral swamp conditions to semi-permanent water about 1500 years ago. Disturbance to the hydrological regime in the European settlement phase has seen the proliferation of the aquatic herb *Myriophyllum* and increases in Restionaceae and *Melaleuca* as previously swamp margin communities expanded over the wetland. A *Eucalyptus* woodland with an open heath understorey characterised the dryland vegetation. *Allocasuarina* was a significant component of the regional vegetation. Increased plant diversity of the woodland understorey and an expansion of wetter forest elements were recorded after 3200 BP, probably due to an increase in climatic variability and associated higher burning levels, both natural and anthropogenic, and generally higher rainfall, respectively. Marked changes in the dryland record, which include a sharp decline in *Allocasuarina* percentages, the introduction of *Pinus* and exotic herbs, as well as an increase in the density of the shrub layer, are associated with European settlement and possibly alteration to fire regimes.

POLLEN preserved in swamp sediments provides a record of past vegetation and environmental change. A body of evidence from a range of palynological studies (see Dodson et al. 1992; Kershaw 1992, 1995) has provided a history of late Quaternary vegetation and climate for the Victorian region. Although major trends in environmental change between sites are similar, details of vegetation and climatic interactions reflect the range of topographic, geological and other local variables represented. The pollen analysis of accumulated swamp sediments from a wetland within Greens Bush on the Southern Mornington Peninsula, Victoria, details changes in vegetation during the mid to late Holocene and provides further evidence for regional variation in Victorian palaeoenvironments including that associated with the impact of human settlement.

THE STUDY AREA

Greens Bush (38°25′S,144°52′E) is part of Point Nepean National Park located about 75 km south of Melbourne. It is a 900 ha bushland remnant, 9 km south of Arthur's Seat on the Mornington Peninsula, Victoria (Fig. 1).

The climate of the study area is temperate with a maritime influence. Estimates from the climatic prediction system BIOCLIM (Busby 1991) indicate that Greens Bush receives an annual mean rainfall of 895 mm of which 273 mm falls in the winter quarter and 161 mm in the summer quarter. The annual mean temperature is about 13.4°C, with a mean minimum temperature in the coldest month of 5.4°C and a mean maximum temperature in the warmest month of 24.4°C. As with other Victorian coastal sites, westerly winds predominate and mean monthly wind speed varies from 10 to 30 km $hour^{-1}$. Relative humidity is moderately high throughout the year and ranges between 70–84% (Seaheti & Scott 1986).

Greens Bush lies approximately 120 m above sea level on an undulating topography of subdued siliceous dunes derived from Pleistocene calcarenite (Keble 1968). The soils are sandy podzols with humic podzols in low-lying areas.

The regional vegetation of the Mornington Peninsula has been described by Calder (1972, 1986). *Allocasaurina verticillata–Melaleuca lanceolata* woodland was the major association on the calcareous sands west of the study site. However, during the mid-Nineteenth Century timber cutters

and limeburners depleted this community (Calder 1986). The *A. verticillata* community has been largely replaced by *Leptospermum laevigatum* scrub. Eucalypt woodland and heathland are dominant on the siliceous sands whereas open eucalypt forest characterises the heavier soils of the region. Wet sclerophyll forest is associated with the moist gullies and creek lines (Conn 1993).

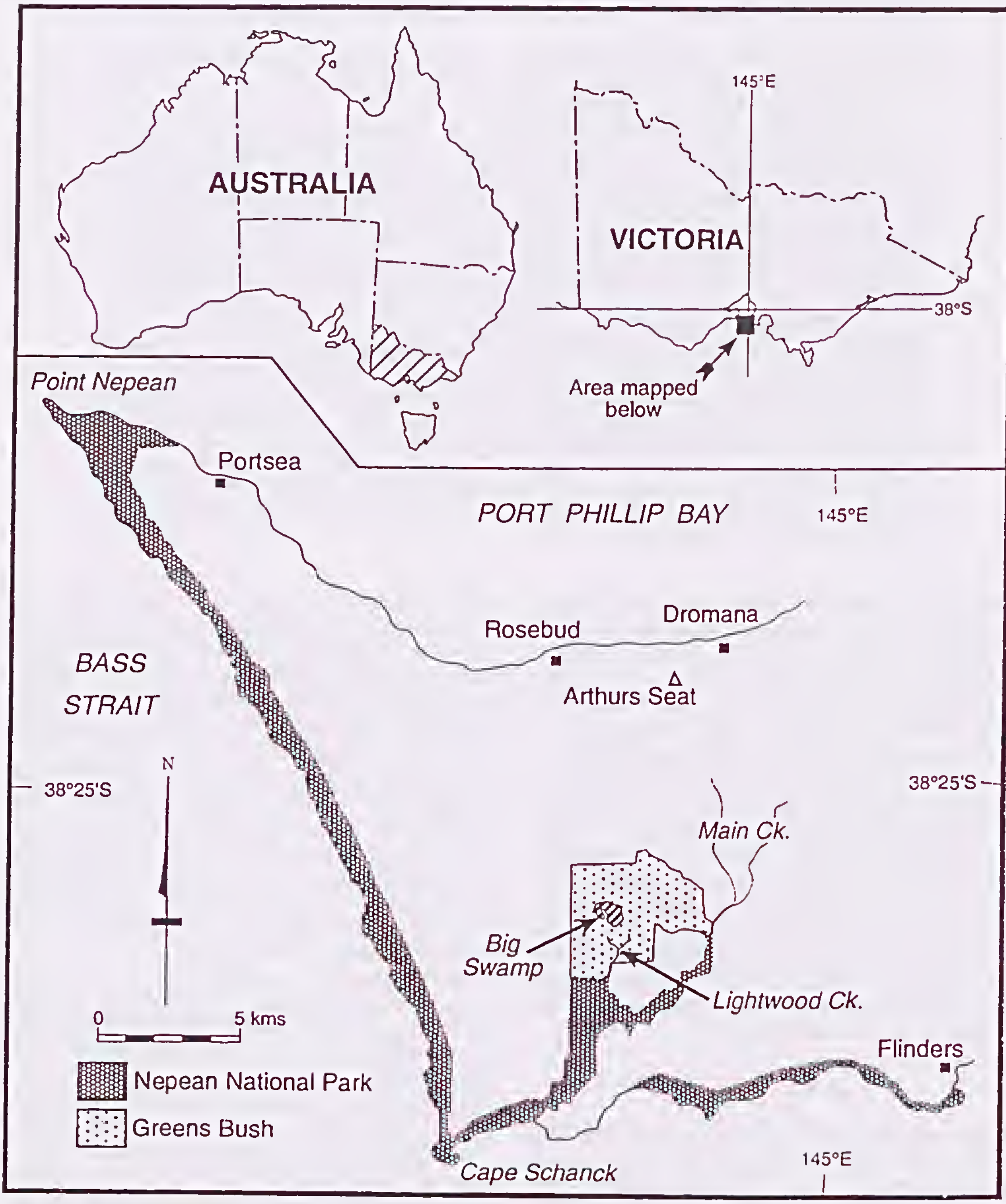


Fig. 1. The location of the study area.

In areas of poor drainage *Melaleuca squarrosa* scrub occurs. Calcarenite cliffs and unconsolidated coastal dunes between Cape Schanck and Point Nepean support a coastal flora which includes *Ozothamnus turbinatus*, *Leucopogon parviflorus*, *Alyxia buxifolia* and chenopods such as *Rhagodia candolleana* (Scaheti & Scott 1986; Barson & Calder 1981).

The vegetation of Greens Bush comprises heathland, woodland, forest, scrubs and swamps (Parr-Smith & Smith 1978). Heathland occurs on the drier sand dune crests and is dominated by *Xanthorrhoea australis*, *Leptospermum myrsinoides*, *Banksia marginata*, *Hypoleana fastigiata*, *Epacris impressa* and Fabaceae such as *Dillwynia glaberrima* and *Aotus ericoides*. Woodland communities are found on the sandy ridges and slopes. The woodland communities comprise a canopy of *Eucalyptus obliqua* with a heathy understorey of *Monotoca scoparia*, *Amperea xiphoclada*, *Leptospermum myrsinoides* and *Pteridium esculentum*. The heathland and woodland communities have affinities with *Leptospermum myrsinoides* heathland (WPC 8.3) described by Opie et al. (1984) and Conn (1993), sand heathland (LCC 1991) and tea-tree heath described by Cheal et al (1989) . The presence of *Xanthorrhoea australis* is a distinctive component of the Greens Bush communities. Forest units have a mixed canopy of *Eucalyptus obliqua* and *Eucalyptus radiata* with a lower stratum comprising *Acrotriche serrulata*, grasses such as *Poa labillardieri* and the herbs *Viola hederacea*, *Hydrocotyle hirta* and *Gonocarpus tetragynus*. Forest units are scattered on gentle, well drained slopes. In the incised valleys of Lightwood and Main creeks, wet sclerophyll communities are found. The community is characterised by a canopy of *Eucalyptus viminalis* and *Eucalyptus obliqua*, a mid-stratum of *Prostanthera lasianthos*, *Acacia melanoxylon*, *Olearia argophylla* and *Pomaderris aspera*, with the ferns *Dicksonia antarctica*, *Calochlaena dubia* and *Blechnum nudum* present in the lower stratum (Conn 1993). The wet sclerophyll community has some affinities to wet sclerophyll forest (Mel 9.2, 9.3) described by Cheal et al. (1989). In waterlogged sites a *Melaleuca squarrosa* scrub dominates over a closed layer of *Gleichenia microphylla* and the rush *Empodisma minus*. In areas of seasonally poor drainage, small remnants of wet heathland persist and comprise species such as *Sprengelia incarnata*, *Epacris obtusifolia* and *Allocasuarina paludosa*. Interdunal swamps are seasonally inundated and dominated by sedges such as *Lepidosperma longitudinale* and *Baumea rubiginosa*. In locations where sufficient water exists throughout the year, the swamps contain a suite of semi-aquatic species and often exhibit distinct zonation. The swamp communities of Greens Bush have close affinities to swamp sedgeland (WPC 14.2, 14.3) described by Opie et al. (1984), the Land Conservation Council (1991) and Conn (1993).

Greens Bush is a conservation area of significant ecological importance. With only 14% of the Peninsula supporting natural vegetation, about half in viable remnants, Greens Bush represents one of six remaining larger reserves. Several of the plant communities of Greens Bush are regionally rare, especially the swamp and wet sclerophyll communities. The swamp communities are reported to be of high ecological and conservation value (Larwill & Costello 1992). Similar swamp communities found in the Westernport Region are considered rare (Opie et al. 1984). Calder (1986) concluded the wet sclerophyll forests of the Peninsula, including those found in Greens Bush, to be of significant conservation and biological value for the occurrence of many species which are confined to this vegetation community on the Mornington Peninsula. Twenty-two per cent of the 144 species of indigenous flora identified in a preliminary survey of Greens Bush by Carr et al. (1988) were of State or regional significance. *Euphrasia collina* ssp. *muelleri*, an endangered species (Gullan et al. 1990), is found in the heathland community of Greens Bush.

Prior to European settlement the Mornington Peninsula and Westernport Region, including the area now designated as Greens Bush, was inhabited by a sub-clan of the Bunurong, the Mayone-Balluk, (baloke meaning swamp) (Barwick 1984). Archaeological research attests to the importance of swamps for aboriginals in the supply of food resources, potable water and raw materials. Evidence seems to suggest that the swamp environments of the hinterland were the long term focus of occupation (Sullivan 1981; Gaughwin 1981; Ellender & Weaver 1990). Gaughwin (1983) illustrated a pre-contact land use model in which the coastal margins were relatively unimportant in the food quest and the main focus was on the hinterland with campsites on the ecotone between woodland and wetland. It seems likely that local Bunurong used fire for manipulation of food resources and access purposes with the suggestion that tea-tree scrub was regularly burnt (Gaughwin 1981).

The European land use history and settlement of Greens Bush is sketchy. In the 1840s and 1850s the area in and around Greens Bush was taken up for large cattle runs. In 1926 Edward Green

purehased mueh of the land now gazetted as national park. The land was used for grazing, assoeiated land elearanee and pasture improvement, with the eentral bloek retained in its 'natural' state. Aneedotal reports suggest that burning took plaee, and, although the extent and frequeney of burning is unknown, there is evidenee to support the notion of an inereasing number of fires or inereasing fire intensity immediately following European settlement (Muller 1993). The last major fire burnt Greens Bush in 1962.

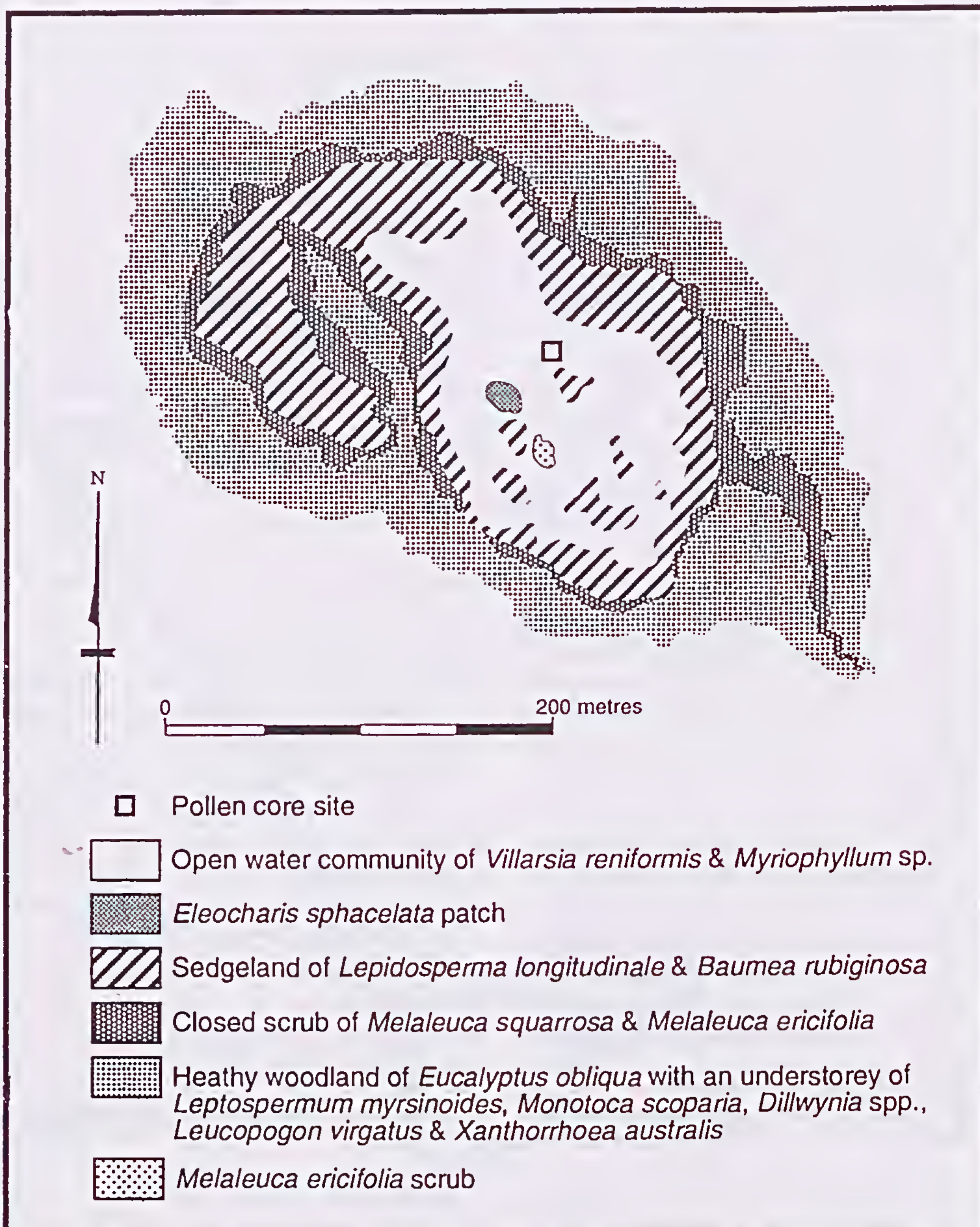


Fig. 2. The pollen core site in relation to the vegetation communities on and surrounding Big Swamp.

THE POLLEN SITE

Material for pollen analysis was obtained from Big Swamp, a shallow freshwater marsh (Corrick & Norman 1988) located in the headwaters of Lightwood Creek, in the western block of Greens Bush (Figs 1, 2). The swamp is about 260 m long and 150 m across at its widest point. Its long axis runs NW–SE. The surface of the swamp is relatively flat with only a slight slope toward a small outlet at its south-eastern end. The outlet flows into a tributary of Lightwood Creek. The swamp lies in an interdunal swale.

The hydrology of the swamp is affected by seasonal variations in precipitation and changes in the groundwater table. Similar hydrological patterns have been found on siliceous dunes in the region (Shugg 1991). In April 1991 the water table was 10 cm below the swamp surface, with surface water levels attaining a depth of 30–50 cm by August. Water levels fluctuated slightly through the summer of 1991–92 with permanent water remaining throughout 1992.

The vegetation of the swamp shows a distinct zonal pattern (Fig. 2). Swards of *Villarsia reniformis* and *Myriophyllum crispatum* characterise the open waters of the swamp with sporadic occurrences of *Amphibromus recurvatus* (Plate 1). A patch of *Eleocharis spachelata* has an isolated occurrence in the centre of the swamp. In the surrounding shallower waters, a sedgeland of *Lepidosperma longitudinale* and *Baumea rubiginosa* dominates with *Baumea tetragona* less prolific (Plate 2). The margins of the swamp are colonised by a closed scrub of *Melaleuca squarrosa* and *Melaleuca ericifolia*, with *Empodisma minus*, *Selaginella uliginosa* and *Sphagnum subsecundum* forming a dense, matted ground cover. Emergent *Eucalyptus ovata* occur in the closed scrub. The surrounding woodland community is dominated by *Eucalyptus obliqua* with a heath understorey of *Monotoca scoparia*, *Xanthorrhoea australis* and *Leptospermum myrsinoides* (Plate 3). *Leptospermum continentale* is a common species of both the heathy woodland and closed scrub communities. *Banksia marginata*, *Dillwynia glaberrima*, *Amperea xiphoclada*, *Leucopogon virgatus* and *Acacia suaveolens* are less prominent species in the

Plate 1. Open water community of Big Swamp with swards of *Villarsia reniformis* (January 1992; photo: M. Jenkins).

Plate 2. Sedgeland of *Lepidosperma longitudinale*, Big Swamp (August 1992; photo: M. Jenkins).

Plate 3. Heathy woodland of *Eucalyptus obliqua* with an understorey of *Leptospermum myrsinoides*, *Monotoca scoparia* and *Xanthorrhoea australis* surrounding Big Swamp (November 1992; photo: M. Jenkins).

heathy understorey. Herbaceous taxa of the woodland community include *Lagenifera stipitata* and *Burchardia umbellata*.

The swamp is considered of State conservation significance because of its high ecological and conservation value (Larwill & Costello 1992). The wetland plant communities are regionally rare (Carr et al. 1988; Fitzsimons 1989). The continuity of the ecological gradient between swamp sedgeland, surrounding *Melaleuca* scrub and heathland, make the mosaic of vegetation highly significant. Frood and Calder (1987) consider both *Melaleuca* scrub and swamp sedgeland as depleted in Victoria, and in need of conservation. A number of plant species recorded in and around the swamp are considered regionally significant in both the Melbourne and Westernport regions. These taxa include *Amphibromus recurvatus*, *Villarsia reniformis*, *Spiranthes sinensis*, *Utricularia* spp. and *Xyris gracilis* (Beauglehole 1983; Opie et al. 1984; Larwill & Costello 1993). The wetland is also of an important habitat for Latham's Snipe (listed on the Japan–Australia Migratory Bird Agreement).

METHODS

The sediment core for pollen analysis was taken within the open water community close to the centre of the swamp (Fig. 2). The core, 118 cm in length, was extracted in sections with a D section sampler (Moore & Webb 1978). It was described, in the laboratory, according to the Troels-Smith (1955) system of sediment stratigraphy.

The core was then sampled at 4 cm intervals from 2 cm to 118 cm depth with an additional sample taken from the surface. Slices of 1 cm thickness were removed and a 1 cm^3 subsample extracted from the uncontaminated centre of each slice for pollen and charcoal analysis. The remainder of each slice was used for moisture and organic determinations, which involved oven drying at 100°C for 24 h and furness ignition at 500°C for 2 h respectively.

The 1 cm^3 samples were treated by the standard potassium hydroxide, hydrogen fluoride digestion and acetolysis methods as described by Faegri & Iverson (1975) in order to remove the sediment matrix and thereby concentrate the pollen and charcoal. The residue from each sample was immersed in a known amount of silicone oil and stored in vials. A measured volume of each sample was then mounted on microscope slides for pollen counting and identification and for charcoal counting.

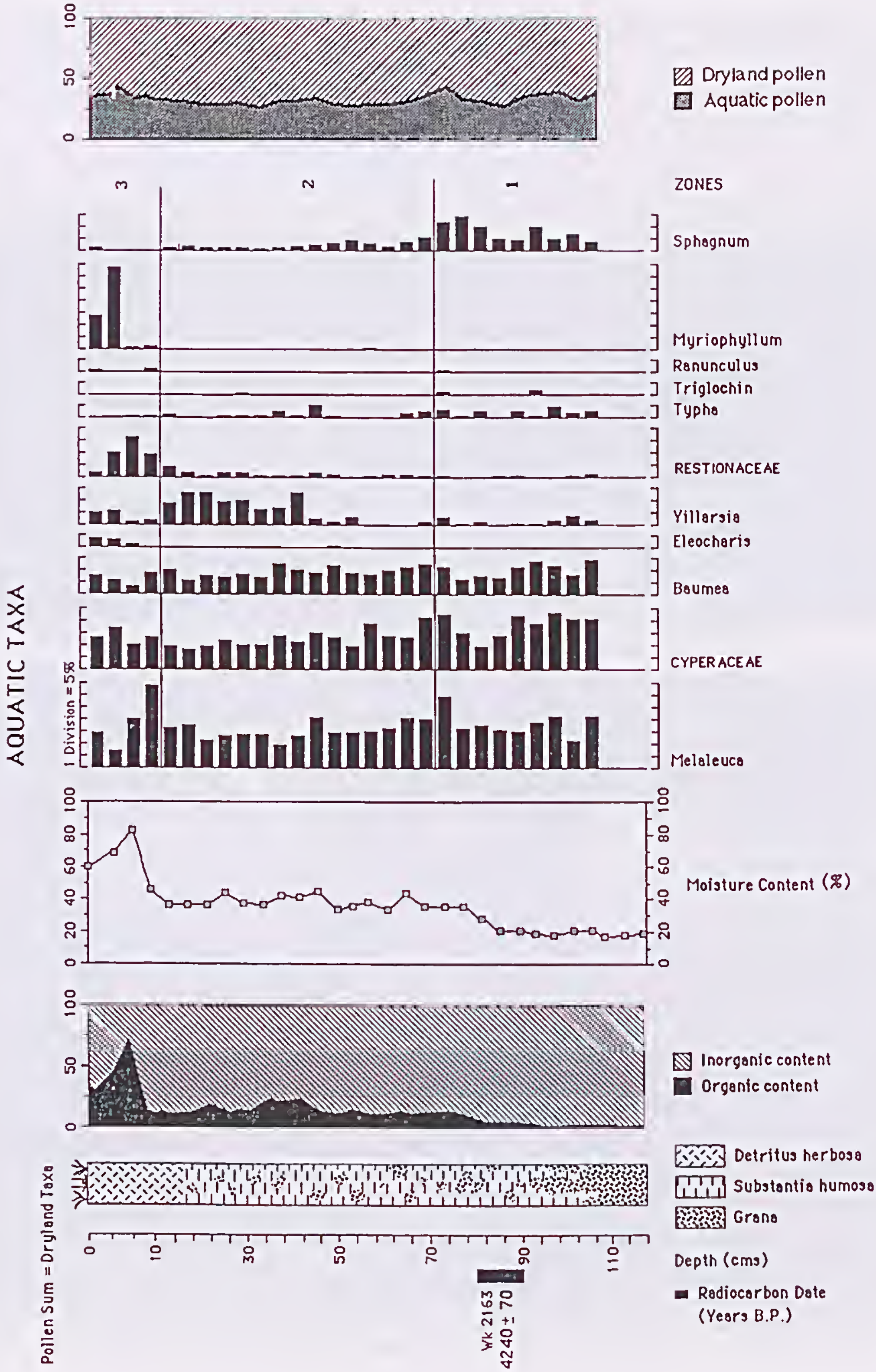
Identification of pollen grains and spores was made by comparison with reference slides and photographs located in the Department of Geography and Environmental Science, Monash University. The Myrtaceae were the most problematic group to identify because of considerable overlap in morphological features between genera and the presence of degraded grains. *Eucalyptus* pollen was distinguished from other genera by its equatorial diameter (17–24 μm), parasyncolpate apertures, thickened pores and the presence of a polar island. *Melaleuca* were classified according to their parasyncolpate/syncolpate apertures and equatorial diameter (16–20 μm). *Leptospermum* are thin pored, syncolpate grains with an equatorial diameter of 12–18 μm, sometimes with a faintly scabrate exine. Pollen grains with characteristics intermediate between *Leptospermum* and *Melaleuca* were classified as Myrtaceous shrubs. *Allocasuarina* pollen was separated into species based on grain size (Kershaw 1970; Dodson 1974; Hooley et al. 1980). *Allocasuarina* pollen grains with an equatorial diameter of >32 μm were classified as *Allocasuarina verticillatta*. *Allocasuarina* pollen <32 μm was classified as *Allocasuarina littoralis*. Native and introduced species of *Plantago* were separated on the degree of aperture thickening.

Two hundred dryland pollen grains were counted on each slide using an Olympus binocular CHA microscope at a magnification of 600×. Pollen grains were counted along evenly spaced transects over the whole of each slide to account for the preferential distribution and behaviour of different sized particles in the oil medium. The number of transects required to count a minimum of 200 dryland pollen grains was recorded to allow an estimate of pollen density.

All opaque, black angular fragments greater than 10 μm were classified as charcoal. The abundance of charcoal as square millimetres per cubic centimetre was calculated by the Point Count Estimation Technique outlined by Clark (1982).

A radiocarbon (^{14}C) date for the core was determined from sediment taken at a depth of 80–90 cm. The low organic content of the basal sediments necessitated a bulk sample to obtain an accurate minimum age for initial swamp formation. Root fragments which may have been younger than the sediment matrix were removed. The sample was dispatched to the Radiocarbon Dating Laboratory at the University of Waikato, New Zealand for analysis.

Inferred dates for the pollen zones and basal sediments were determined from the radiocarbon date, the time of arrival of Europeans, and the


Dryland pollen
Aquatic pollen
ZONES
3
2
1
Sphagnum
Myriophyllum
Ranunculus
Triglochin
Typha
RESTIONACEAE
Villarsia
Eleocharis
Baumea
CYPERACEAE
Melaleuca
AQUATIC TAXA
1 Division = 5%
Moisture Content (%)
Inorganic content
Organic content
Detritus herbosa
Substantia humosa
Grana
Depth (cms)
Radiocarbon Date
(Years B.P.)
Wk 2163
4240 ± 70
Pollen Sum = Dryland Taxa

dryland pollen accumulation rate, on the assumption of a constant influx of pollen through time. The time of European arrival was identified by the first presence of exotic pollen in the record.

RESULTS

The results of pollen, charcoal, moisture and organic content analysis, along with the core stratigraphy are shown diagrammatically in Figs 3 and 4. Values for all individual pollen taxa are expressed as percentages of the native dryland plant pollen sum for each sample. Pollen and charcoal particle concentrations are shown as numbers per cm³ and mm² per cm³ respectively. Moisture content is shown as a percentage of the wet weight of the sample. Organic content is shown as a percentage of the dry weight of the sample after ignition at 500°C for 2 h.

The pollen diagram has been divided into zones on the basis of major changes in the representation of pollen taxa and the presence of taxa indicative of a particular vegetation type.

Description of the pollen zones including sediment stratigraphy

Zone 1 (118–70 cm) c. *4500 BP*–c. *3200 BP.* The basal sediments from 118 to 106 cm consisting of a mottled, light grey grana (sand) with a very low organic content (2–3%) and a moisture content of only 18–20% are devoid of pollen. Substantia humosa (decomposed peat) forms the matrix of the sediments between 106 and 70 cm with a grana component decreasing in representation toward the top of the unit.

The major aquatic pollen taxa within this zone are *Melaleuca*, *Baumea* and other Cyperaceae, with *Sphagnum* recording its highest representation in the diagram. *Typha*, *Triglochin* and *Villarsia* have low and variable percentages.

The dryland woody pollen taxa *Allocasuarina*, *Eucalyptus and Leptospermum* have consistently high percentages with *Allocasuarina* dominant except for a dip recorded at 86 cm. Asteraceae is the major woody/herbaceous taxon with Poaceae the major herbaceous taxon. Other dryland woody and herbaceous taxa, as well as pteridophytes have low and generally sporadic representation.

Pollen density is at its lowest level for the diagram in the basal part of the zone, where there are also many eroded grains, but increases sharply between 86 and 78 cm depth. Dryland taxa constitute greater than 50% of the pollen assemblage with woody taxa the most significant proportion of the dryland component. Charcoal values increase steadily through the zone.

Zone 2 (70–14 cm) c. *3200 BP*–c. *150 BP.* The sediments remain similar to those in the upper part of the last zone except towards the top where there is a change to more fibrous *Detritus herbosus* or peat. The organic content remains below 25% and water content, although increasing gradually through the zone, does not exceed 40% of wet weight.

Melaleuca, *Baumea* and Cyperaceae persist as the dominant aquatic taxa with *Villarsia* becoming an additional significant component in the top half of the zone. *Sphagnum* percentages decrease markedly while Restionaceae is consistently present and has an increased percentage in the top sample. The only other notable aquatic, *Typha* has low and variable representation.

Allocasuarina more clearly dominates the dryland component, particularly in the middle of the zone where values of both *Eucalyptus* and *Leptospermum* are relatively low. Asteraceae percentages are slightly reduced but the woody/herbaceous component is maintained by higher values of both Chenopodiaceae and *Amperea.* Poaceae maintains its representation. The zone shows generally high dryland pollen diversity with the more consistent presence of the woody taxa *Pomaderris*, *Dodonaea* and Epacridaceae, the herbaceous taxa *Plantago* (native), *Hydrocotyle* and *Gonocarpus* and the tree fern *Dicksonia.* Pollen density is highest close to the base of the zone with a gradual decline toward the top. Dryland taxa continue to dominate the pollen assemblage with woody taxa the major dryland component.

Within this zone, pollen density generally decreases from an early highest peak for the diagram. Overall charcoal abundance increases through the zone, though there are marked fluctuations in its representation.

Zone 3 (14–0 cm) c. *150 BP–Present.* This section of the deposit consists of a sub-fibrous, dark brown detritus herbosus (peat) with macro plant remains discernible in the top 10 cm. Organic content reaches its maximum of 72% at 6 cm with a corresponding peak in moisture content.

Fig. 3. Aquatic pollen diagram from Big Swamp. The values for all taxa are expressed as percentages of total dry land pollen for each sample.

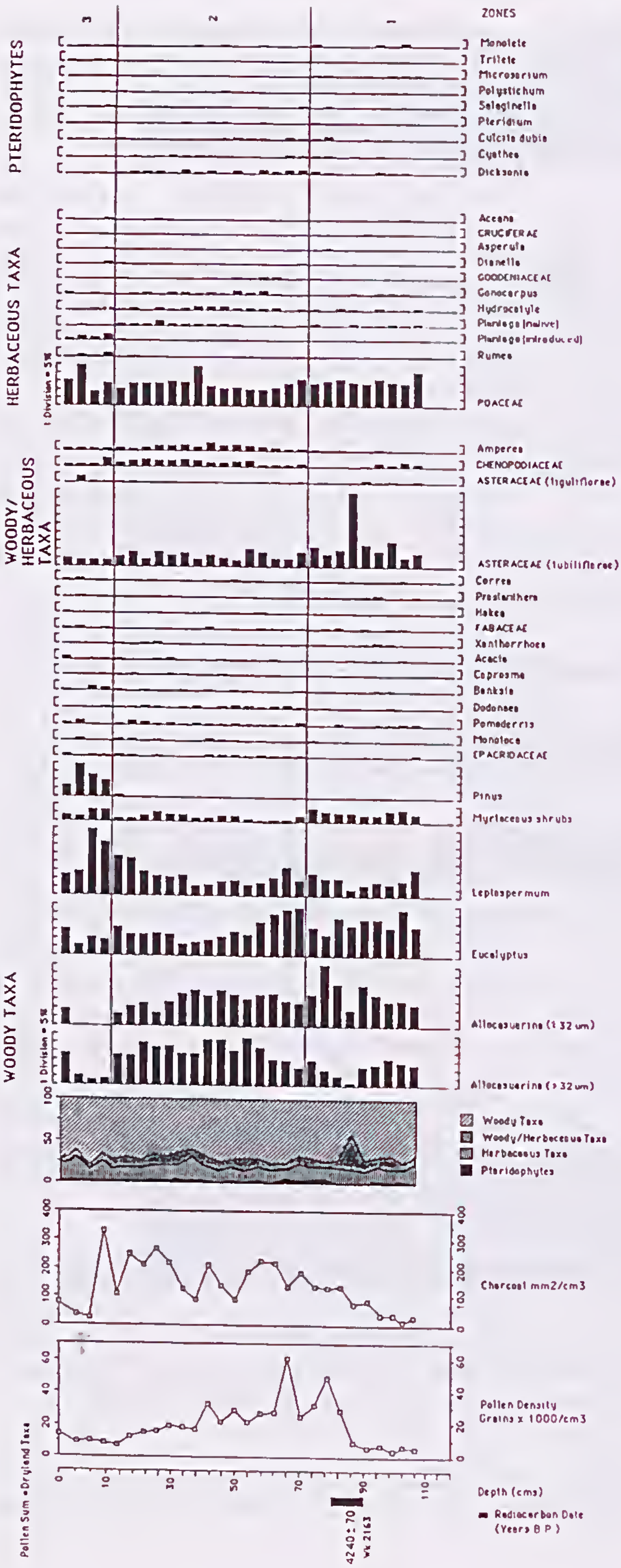


Fig. 4. Dry land pollen diagram from Big Swamp. The values for all taxa are expressed as percentages of total dry land pollen for each sample.

The base of the zone is characterised by a significant change in the composition and abundance of both aquatic and dryland pollen taxa while there are substantial variations within it. Within the aquatic taxa, *Melaleuca* records its highest value for the record at 10 cm depth before declining again, Restionaceae has high values through much of the zone while *Eleocharis* and particularly *Myriophyllum* become important components of the flora, for the first time, within the topmost sample. *Villarsia* values have declined and *Sphagnum* loses its consistent representation.

The dryland component is marked by very low values of *Allocasuarina*, except in the top sample, highest values for *Leptospermum* and *Banksia* within the diagram in the basal two samples of the zone, and the introduction of the exotic taxon *Pinus*. *Allocasuarina* (<32 μm) was only recorded in the topmost sample. Poaceae records its highest representation in this zone. *Plantago varia* declines in representation with the introduction of the exotic *Plantago lanceolata* while the herbaceous taxon *Rumex*, probably also from exotic plants, records low percentages. Ferns are poorly represented and no tree fern spores were recorded.

Pollen density declines further within this zone, before a slight increase toward the surface. The percentage of aquatic taxa remains relatively constant and dryland taxa continue to dominate the pollen assemblage. Charcoal abundance has a peak value for the diagram in the basal sample of this zone before declining to low levels.

DISCUSSION

Swamp development and aquatic vegetation

The swamp, which lies on a former drainage line of Lightwood Creek, began to accumulate polleniferous, organic sediments around 4500 BP. The reason for swamp initiation at this time is difficult to determine. It is possible that a decrease in effective precipitation after the mid-Holocene 'climatic optimum', dated generally to between 7000 and 5000 years BP (Kershaw 1992) led to a reduction in the erosive power of the stream allowing sediment to accumulate rather than being washed out of the system. Such an explanation has been suggested for the development of Tawonga Bog, a lowland site in the Kiewa valley, north-east Victoria (Kershaw & Green 1982), and Jackson's Bog in the Monaro Tablelands, New South Wales (Southern 1982) at this time. However, it is unlikely that Lightwood Creek ever had great erosive power and more feasible alternative explanations include the possibility that previously accumulated sediment was oxidised under dry conditions following the 'climatic optimum' and that some reorganisation of the dune system during this drier phase created a suitable basin for water and hence organic sediment accumulation. Other causal factors may include fire. Firing of the swamp and surrounding catchment may have contributed to the loss of pre-existing sediments through the combustion of peat layers and reorganisation of the dune sands through loss of stabilising vegetation.

The inorganic nature of the basal sediments together with a high proportion of eroded pollen grains in the basal part of zone 1 suggests that ephemeral swamp conditions prevailed. The relatively high percentages of *Sphagnum*, which is noted to undergo sporogenesis when under stress (Kershaw & Gell 1990), and the consistent representation of *Typha* which is able to establish from seed on exposed muds and can tolerate an inorganic substrate, add support to the proposal for the existence of ephemeral swamp. It is likely that the centre of the site was dominated by sedges with patches of *Typha* and open water containing *Villarsia* surrounded by marginal *Melaleuca* thickets. *Sphagnum* moss may have provided an understorey to many swamp communities.

Towards the end of the period represented by zone 1, the higher organic content of the sediment indicates more permanent swamp conditions. However, there is little indication of a vegetation change until the middle of zone 2, estimated to have been about 1500 years BP, when there is a further increase in the organic component and presumably a consistently higher water table. An increase in water level may explain the apparent expansion of *Villarsia* which may have been previously restricted to shallow water depressions due to the fact that it dies back when stranded (Aston 1973), and a decline in *Sphagnum* due to a reduction in water stress.

The European phase (zone 3) is marked by significantly increased variability in the aquatic pollen record. *Myriophyllum* makes a sudden appearance in the pollen spectra of this zone; its high representation possibly induced by nutrient loading of swamp waters and fluctuating water levels as a consequence of land clearance and cattle grazing. Orchard (1986) noted that the genus often grows prolifically in high nutrient waters and has a high propensity to flower when stranded. Other studies (Gell & Stuart 1989; Aitken & Kershaw 1993) have attributed an increase in *Myriophyllum* within very recent times to changes in water quality and yield. The increase in *Myriophyllum* may also be related to

its phenotypic plasticity. This aquatic/paludal genus is able to produce erect, robust stems and spread by the formation of adventitious roots from nodes when stranded (Orchard 1986). The peaks in Restionaceae and *Melaleuca* are consistent with local fluctuations in water level as marginal swamp communities increased their extent, at least initially. Although the pollen spectra indicate some variation in swamp levels, the presence of the emergent macrophyte *Eleocharis* and the submerged hydrophyte *Villarsia* suggest the continued presence of open water communities. The increase in the organic content of sediments and the rapid sedimentation rate, implied by low pollen densities, are consistent with a productive swamp.

The aquatic pollen data indicates that the conservation of wetland plant communities in Greens Bush is reliant upon limiting degrading processes such as eutrophication and alteration of catchment hydrology. The weedy expansion of the aquatic herb *Myriophyllum*, in response to altered water quality and hydrology, may result in the exclusion of small, localised populations of significant species such as *Utricularia* spp. or *Spiranthes sinesis*, with a concomitant decrease in floral diversity. Similarly, the spread of *Melaleuca* thickets over the swamp surface, with changes in the hydrological regime through altered catchment processes, may lead to a reduction of sedge and open water communities and a decline in these regionally rare plant community types.

Terrestrial vegetation

The vegetation of the region was relatively constant during the pre-European period. An *Allocasuarina verticillata* (represented by *Allocasuarina* >32 μm) open woodland probably dominated the vegetation of the Nepean Peninsula west of Selwyn's Fault as evidenced by the relatively high percentages of this regional pollen type in the record and early historical accounts (Tuckey 1805). The constant background presence of Chenopodiaceae in the pollen spectra reflects the regional presence of coastal communities colonised by such taxa as *Atriplex cinerea* and *Rhagodia candolleana*. Similarly, the presence of *Pomaderris*, *Prostanthera*, *Coprosma* and the ferns *Dicksonia* and *Cyathea* in the record highlights the existence of wet sclerophyll communities in the entrenched gullies of Lightwood and Main Creek.

A *Eucalyptus* woodland with a dry, open heath understorey with a mix of herb taxa most likely characterised the dryland vegetation immediately surrounding the site over the last 4500 years (zones 1, 2). *Leptospermum* has been a major component of the understorey with Epacridaceae, *Banksia*, *Acacia* and *Amperea* comprising lesser components of the shrub strata. Taxa such as *Hydrocotyle*, Goodeniaceae and *Haloragis* make up the herb component. Significant percentages for *Allocasuarina littoralis* (represented by *Allocasuarina* <32 μm) suggest that this species may have been a more substantial component of the surrounding sclerophyll vegetation in the pre-European phase than indicated by its present distribution.

After 3200 BP, the dryland vegetation became more diverse with an increased representation of understorey and herbaceous taxa. Greater diversity in the vegetation during the period represented by zone 2 may be related to increased climatic variability with intensification of the El Nino–Southern Oscillation (ENSO) (McGlone et al. 1992; Aitken & Kershaw 1993) limiting competitive exclusion of taxa due to fluctuations in moisture regimes. Higher levels of charcoal in this zone suggests that increased burning, possibly due to the climatic variability, was also a contributing factor. Despite this evidence for climatic variability, the more consistent values for *Pomaderris* and *Dicksonia* in zone 2 suggest a slight expansion in wet sclerophyll elements during this period and support the aquatic evidence for generally higher precipitation levels. This feature of the climate also has regional support (Kershaw 1995). The synchronous increase in moisture dependent species and understorey taxa tolerant of disturbance are consistent with patterns described elsewhere in the Australasian region during the latter part of the Holocene (McGlone et al. 1992).

There is some ethnohistorical evidence for anthropogenic burning as a contributory explanation for increased fire and a more diverse vegetation at the site after 3200 BP. Deliberate burning by aboriginals for resource utilisation and access purposes has been noted with the suggestion that areas were regularly burnt (Gaughwin 1981). However, the extent and nature of the burning has not been fully determined. Ellender (1991) hypothesises that exploitation of hinterland swamps, similar in nature to Big Swamp, may have been associated with purposeful firing of the surrounding vegetation. It would seem that anthropogenic influence may in part be implicated in the vegetation dynamics of the site.

The European phase of the terrestrial record (zone 3) shows significant changes in pollen assemblages. The presence of *Pinus* pollen characterises the phase and corresponds with the establishment of softwood plantations and

windbreaks on the southern Mornington Peninsula during the late 1800s. The sudden decline in *Allocasuarina* is probably related to land clearance and timber harvesting (Calder 1972). Decline in the abundance of *Allocasuarina* with European settlement has been documented in a number of palaeoecological studies (e.g. D'Costa et al. 1989; Head 1988). However the subsequent apparent recovery of the taxon has not been noted elsewhere in the region and it may be unwise to place too much significance on the evidence from one sample.

Leptospermum shows significant increases at the beginning of the European phase and is indicative of an increase in the density of the shrub layer. *Leptospermum myrsinoides* and, to a lesser extent, *Leptospermum continentale* are the dominant taxa in the heath understorey/heathland of the site and the most likely constituents of the *Leptospermum* sum given the limited dispersal of the genus (Dodson 1983). *Leptospermum myrsinoides* flowers profusely and its high representation may be attributed to post fire regeneration following the episode(s) of intense fire noted by the high charcoal level. An increase in the intensity and or frequency of burning in the late 1800s and early 1900s has been suggested (Muller 1993). The decrease in *Leptospermum* pollen toward the surface may indicate senescence of individual plants and a decline in the phenological capacity of *L. myrsinoides* as a consequence of more recent fire exclusion policies. The last major fire in Greens Bush was reported in 1962 (Muller 1993).

In the basal samples of the European phase of the terrestrial pollen record, taxa show differential response to fire. *Leptospermum* and *Banksia* increase their representation in response to fire, whereas *Pomaderris* and *Allocasuarina littoralis* (*Allocasuarina* <32 μm) decline. The decline in *Allocasuarina littoralis* may be related to its incapacity to resprout vegetatively following intense fire and/or lack of a nearby seed source as a consequence of timber harvesting. Similarly, the decline in *Pomaderris* may be related to its fire sensitivity.

As indicated by the pollen record, the management and conservation of plant communities in Greens Bush is in part related to fire regime. The ecological manipulation of fire needs to address the varied response of individual taxa and the differing fire requirements of wet sclerophyll and heathland communities alike. Strategies such as mosaic burning, the provision of buffer zones to protect from weed invasion, appropriate fire frequencies and monitoring programs (Gill & Nicholls 1989) are required. In heathland, fire is an integral component of the vegetation dynamics and important for the provision of regeneration opportunities. Frequency of heathland burning is a major determinant of persistence and regeneration possibilities of dominant taxa, with both long term absence and frequent fire capable of irreversible change in the heathland community (Cheal 1996). Mosaic burns provide the opportunity to assess the effectiveness of differing fire regimes, provide regeneration opportunities and limit the catastrophic effects of wildfire through variations in fuel load. In wetland communities the incidence of fire is rare, but fire protection may be needed to lessen the possibility of peat fires. In wet sclerophyll communities, an inappropriate fire regime could lead to a change in the composition of the understorey, an increase in weed invasion and the elimination of fire sensitive taxa. Ashton (1981) and Gill (1993) note the fire sensitivity of wet sclerophyll taxa such as *Prostanthera lasianthos* and *Pomaderris aspera* and changes in the floristics of wet sclerophyll forest in response to varied fire frequency. Logistical and park boundary considerations such as edge effects, and spread of fungal pathogens will affect the ecological manipulation of fire in Greens Bush. It is clear that management actions must respond to the results of monitoring and the observed response of plant taxa (Purdie & Slatyer 1976; Noble & Slatyer 1980) as well as conservation objectives and logistic constraints. The pollen record suggests that an inappropriate fire regime has the potential to lead to long term changes in plant community composition and structure.

Pasture and agricultural development in Greens Bush during the European period is indicated by the displacement of *Plantago varia* by the introduced *Plantago lanceolata*, the introduction and expansion of the herb *Rumex*, and increases in Poaceae and Asteraceae (Liguliflorae) in the most recent samples. The historical expansion of weedy herbaceous taxa with European land settlement may affect the integrity of the herb component of woodland/forest communities in Greens Bush with a resultant decline in plant diversity.

CONCLUSIONS

With the exception of the last 200 years, the vegetation on Big Swamp and within the Greens Bush region has been relatively stable through most of the last 4500 years. There is some evidence from the dryland vegetation of climate change resulting in increases in effective precipitation and climatic variability from about 3200 years BP,

features which have broad regional expression in Australia and New Zealand. A general increase in the level of burning adds support to the proposed climatic variability. The local site evidence provides partial support for increased precipitation with gradual or stepwise increases in the water table and aquatic vegetation responses from about 3500 to 1500 years BP.

The question of aboriginal burning complicates the interpretation of the vegetation dynamics of the site. The limited evidence suggests that to some extent, anthropogenic burning may have affected the vegetation history of the site prior to European settlement.

Major changes in the vegetation of both the swamp surface and surrounding dry land vegetation have occurred during the time of European occupation. Many of these, such as the reduction in forest and woodland due to land clearance and the establishment of exotics are documented historically. Others such as the differential response of taxa to altered fire regimes and the impact on swamp vegetation of altered hydrology and water quality are revelations that have major implications for the management of 'natural' vegetation within this conservation area.

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REFERENCES

AITKEN, D. L. & KERSHAW, A. P., 1993. Holocene vegetation and environmental history of Cranbourne Botanic Gardens. *Proceedings of the Royal Society of Victoria* 105: 67–80.

ASHTON, D. H., 1981. Fire in tall open-forests (wet sclerophyll forests). In *Fire and the Australian Biota*, A. M. Gill, R. H. Groves & I. R. Noble, eds, Australian Academy of Science, Canberra, 339–366.

ASTON, H. I., 1973. *Aquatic Plants of Australia*. Melboune University Press, Melbourne.

BARSON, M. M. & CALDER, D. M., 1981. The vegetation of the Victorian coastline. *Proceedings of the Royal Society of Victoria* 92: 55–65.

Barwick, D. E., 1984. Mapping the past: an atlas of Victorian clans 1835–1904. Part 1. *Aboriginal Studies* 8 (2): 100–131.

BEAUGLEHOLE, A. C., 1983. *The Distribution and Conservation of Vascular Plants in the Melbourne Area, Victoria*. Western Victorian Field Naturalists Clubs Association, Portland, Victoria.

BUSBY, J. R., 1991. BIOCLIM—a bioclimatic analysis and prediction system. In *Nature Conservation: Cost Effective Biological Surveys and Data Analysis*, C. R. Margules & M. P. Austin, eds, CSIRO, Melbourne, 64–68.

CALDER, W., 1972. *The natural vegetation pattern of t he Mornington Peninsula*. M.Sc. thesis, Department of Botany, University of Melbourne (unpublished).

CALDER, W., 1986. *Peninsula Perspectives: Vegetation on the Mornington Peninsula, Victoria*. Centre for Environmental Studies, University of Melbourne.

CARR, G., MILNE, C., TRUMBLEWARD, A. & DUGGAN, D., 1988. *Preliminary Assessment of the Significance of the Vegetation of Greens Bush*. Indigenous Flora & Fauna Association.

CHEAL, D. C., 1996. Fire succession in heathlands and implications for vegetation management. In *Fire and Biodiversity. The Effects and Effectiveness of Fire Management* Biodiversity Series, Paper No. 8. Biodiversity Unit, Department of the Environment, Sport & Territories, Canberra.

CHEAL, D. C., Lau, J. A., Robinson, R. W., Ellis, J. E. & CAMERON, D. G., 1989. *Sites of Botanical Significance in the Melbourne Area*. Department of Conservation & Environment, Victoria (unpublished).

CLARK, R. L., 1982. Point count estimation of charcoal in pollen preparations and thin sections of sediments. *Pollen et Spores* 24: 523–535.

CONN, B. J., 1993. Natural regions and vegetation of Victoria. In *Flora of Victoria Volume 1 Introduction*, D. B Foreman & N. G. Walsh, eds, Royal Botanic Gardens, Melbourne, Inkata Press, Melbourne, 79–157.

CORRICK, A. & NORMAN, F., 1980. Wetlands of Victoria I. Wetlands and waterbirds of the Snowy River and Gippsland Lakes catchment. *Proceedings of the Royal Society of Victoria* 91: 1–15.

D'COSTA, D. M., EDNEY, P., KERSHAW, A. P. & DE DECKER, P., 1989. Late Quaternary palaeoecology of Tower Hill, Victoria, Australia. *Journal of Biogeography* 16: 461–482.

DODSON, J. R., 1974. Vegetation and climatic history near Lake Keilambete, Western Victoria. *Australian Journal of Botany* 22: 709–717.

DODSON, J. R., 1983. Modern Pollen Rain in south-eastern New South Wales, Australia. *Review of Palaeobotany and Palynology* 38: 249–268.

DODSON, J., FULLAGAR, R. & HEAD, L., 1992. Dynamics

of environments and people in the forested crescents of temperate Australia. In *The Naive Lands*, J. Dodson, ed., Longman Cheshire, Melbourne, 115-159.

Ellender, I., 1991. *A Report on Aboriginal Archaeological Sites in the Royal Botanic Gardens, Cranbourne.* Royal Botanic Gardens.

Ellender, I. & Weaver, F., 1990. *An Archaeological survey of Port Phillip Bay.* Victorian Archaeological Survey.

Faegri, K. & Iverson, J., 1975. *Textbook of pollen analysis.* Munksgaard, Copenhagen.

Fitzsimons, P., 1989. The long battle to save Greens Bush. Part one. *Parkwatch* September: 8–10.

Frood, D. & Calder, M., 1987. *Nature Conservation in Victoria.* Victorian National Parks Association.

Gaughwin, D., 1981. *Sites of Archaeological Significance in the Westernport Catchment. Vol. I.* Environmental Studies Division, Ministry for Conservation, Victoria.

Gaughwin, D., 1983. *Coastal Economies and the Westernport Catchment.* Masters thesis, Division of Prehistory, La Trobe University (unpublished).

Gell, P. A. & Stuart, I. M., 1989. *Human settlement history and environmental impact. The Delegate River Catchment, East Gippsland, Victoria.* Monash Publications in Geography No. 36, Monash University, Clayton, Victoria, 65–66.

Gill, A. M., 1993. Interplay of Victoria's flora with fire. In *Flora of Victoria Volume 1 Introduction*, D. B. Foreman & N. G. Walsh, eds, Royal Botanic Gardens, Melbourne, Inkata Press, Melbourne, 212–226.

Gill, A. M. & Nicholls, A. O., 1989. Monitoring fire-prone flora in reserves for nature conservation. In *Fire Management on Nature Conservation Lands*, N. Burrows, L. McCaw & G. Friend, eds. Proceedings of a National Workshop, Busselton, Western Australia. Department of Conservation & Land Management.

Head, L. M., 1988. Holocene vegetation, fire and environmental history of the Discovery Bay region, southwestern Victoria. *Australian Journal of Ecology* 13: 21–49.

Hooley, A. D., Southern, W. & Kershaw, A. P., 1980. Holocene vegetation and environments of Sperm Whale Head, Victoria, Australia. *Journal of Biogeography* 7: 349–362.

Keble, R. A., 1968. *Geological survey of Victoria, Memoir 17 The Mornington Peninsula.* The Department of Mines, Melbourne.

Kershaw, A. P., 1970. Pollen morphological variation within the Casuarinaceae. *Pollen et Spores* 12: 145–161.

Kershaw, A. P., 1992. Past vegetational and climatic change in Victoria: What can it show? In *Victoria's Flora and Fauna: Can it survive the Greenhouse Effect?* J. Pittock, ed., Victorian National Parks Association, Melbourne, 13–15.

Kershaw, A. P., 1995. Environmental Change in Greater Australia. *Antiquity* 69: 656–675.

Kershaw, A. P. & Gell, P. A., 1990. Quaternary vegetation and the future of the forests. In *Lessons for human survival: nature's record from the Quaternary*, P. Bishop, ed., *Geological Society of Australia Symposium Proceedings* 1: 11–20.

Kershaw, A. P. & Green, J. E., 1983. Tawonga Bog revisited: The history of a low altitude peat deposit. *Victorian Naturalist* 100: 256–259.

Land Conservation Council, Victoria, 1991. *Melbourne Area District 2 Review Descriptive Report.* Government Printer, Melbourne.

Larwill, S. & Costello, C., 1992. *Inventory of Wetlands in the South East Region of Melbourne Water.* Biosis Research Pty Ltd.

Larwill, S. & Costello, C., 1993. *Biological Assessment of Two Wetlands in the Cranbourne Botanic Garden.* Biosis Research Pty Ltd.

McGlone, M., Kershaw, A. P. & Markgraf, V., 1992. El Nino–Southern Oscillation and climatic variability in Australasian palaeoenvironmental records. In *El Nino: Historical and Palaeoclimatic Aspects of the Southern Oscillation*, H. F. Diaz & V. Markgraf, eds, Cambridge University Press, Cambridge, 435–462.

Moore, P. D. & Webb, J. A., 1978. *An illustrated guide to pollen analysis.* Hodden and Stoughton, London.

Muller, G., 1993. *An investigation of the fire history and ecology of* Xanthorrhoea australis *at Greens Bush, Victoria.* A thesis submitted in partial fulfilment of the Master of Environmental Science, Department of Geography & Environmental Science, Monash University, Clayton, Victoria (unpublished).

Noble, I. R. & Slatyer, R. O., 1980. The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. *Vegetatio* 43: 5–21.

Opie, A. M., Gullan, P. K., van Berkel, S. C. & van Rees, H., 1984. *Sites of Botanical Significance in the Westernport Region.* Ministry for Conservation, Victoria.

Orchard, A. E., 1986. *Myriophyllum* (Haloragaceae) in Australia II. The Australian species. *Brunonia* 8: 173–291.

Parr-Smith, G. A. & Smith, P. G., 1978. *The Vegetation of Greens Bush.* National Parks Service, Victoria.

Purdie, R. W. & Slatyer, R. O., 1976. Vegetation succession after fire in sclerophyll woodland communities in southeastern Australia. *Australian Journal of Ecology* 1: 223–236.

Sacheti, U. & Scott, G. A. M., 1986. The vegetation of a coastal sand dune in southeastern Australia: Gunnamatta Beach. *Proceedings of the Royal Society of Victoria* 98: 73–86.

Sullivan, H., 1981. *An Archaeological Survey of the Mornington Peninsula, Victoria.* Occasional Report Series 6. Ministry for Conservation, Victoria.

Shugg, A., 1991. *Botanic Gardens Annexe, Cranbourne. Notes on the Environmental Hydrology and the Swamps of the Dune Landscape.* Resource Policy & Programs Branch, Department of Conservation & Environment.

SOUTHERN, W., 1982. *Late Quaternary vegetation and environments of Jackson's Bog and the Monaro Tablelands, New South Wales.* M.A. thesis, Department of Geography, Monash University, Clayton, Victoria (unpublished).

TROELS-SMITH, J., 1955. Characterisation of unconsolidated sediments. *Danm. Geol. Unders* (ser. IV) 3: 1.

TUCKEY, J. H., 1805. An account of a voyage to establish a colony at Port Phillip in Bass's Strait, on the south coast of New South Wales. In *His Majesty's ship Calcutta, in the years 1802–4.* London.